

**Nb<sub>3</sub>Al R&D  
for  
Future Accelerator Applications**

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KEK

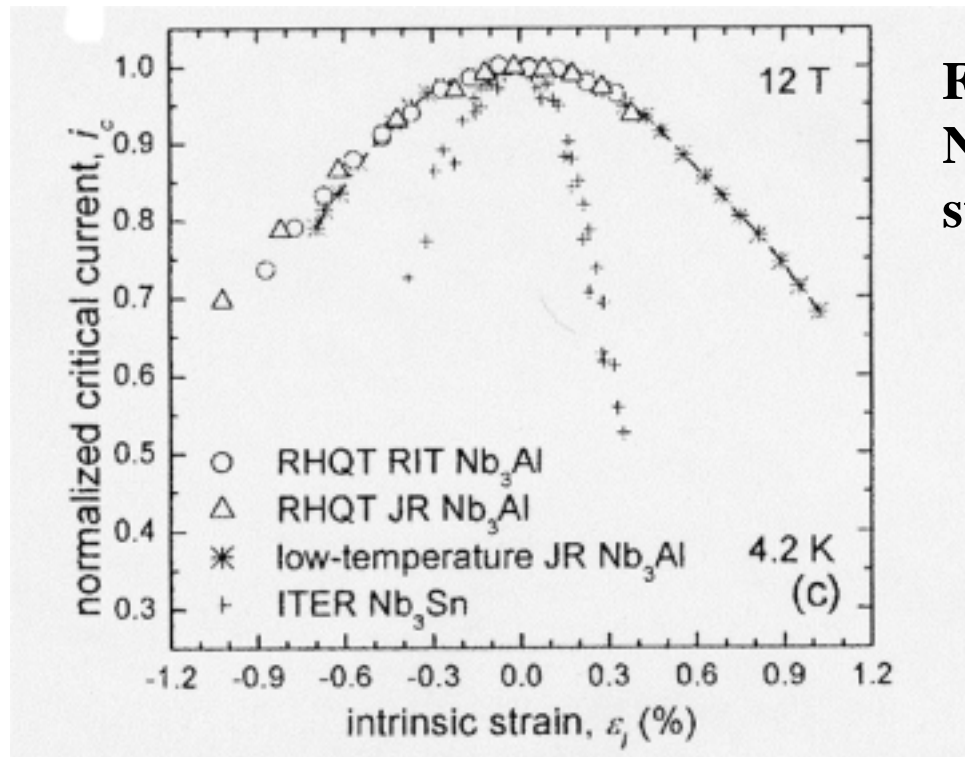
# Outline

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# Introduction

- **Nb<sub>3</sub>Al has better strain tolerance than Nb<sub>3</sub>Sn**
- **Rapid quenching process wires have been developed in NIMS (National Institute for Materials Science), Japan**
  - candidate conductor for a high-resolution NMR system operated at 23.5 T
  - rapid quenching facilities are in operation at NIMS and Hitachi Cable Ltd.
- **KEK started the RQ Nb<sub>3</sub>Al R&D for future accelerator applications in collaboration with NIMS**

## Strain characteristics of Nb<sub>3</sub>Al and Nb<sub>3</sub>Sn wires

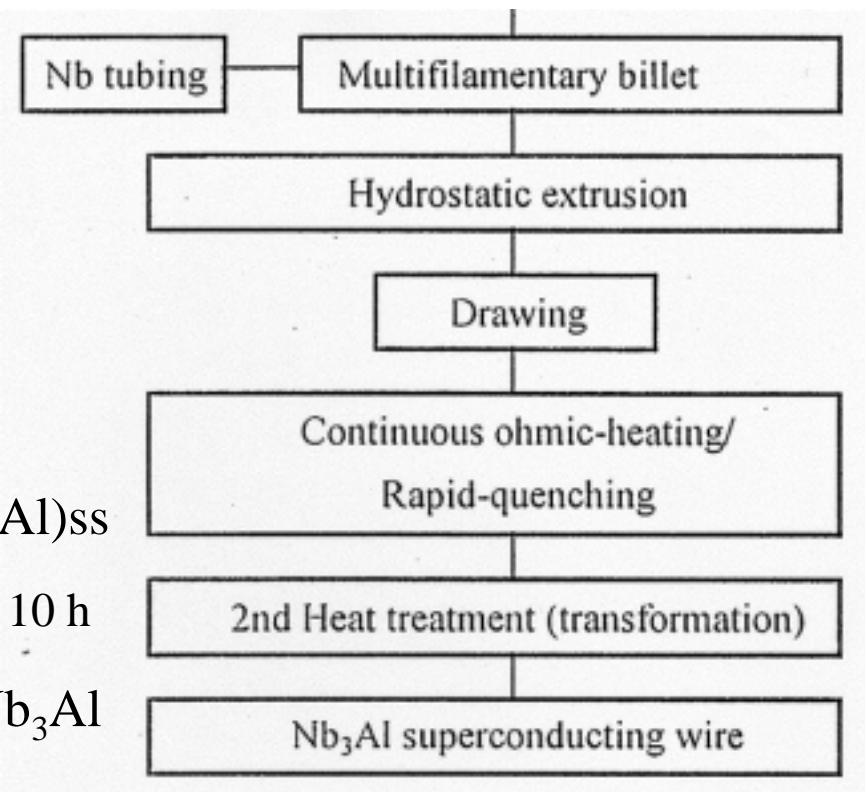
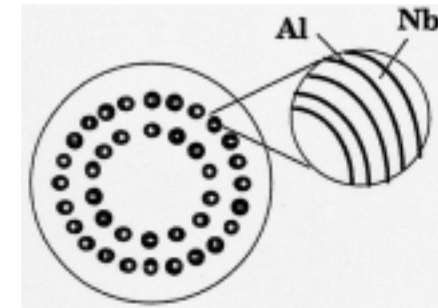
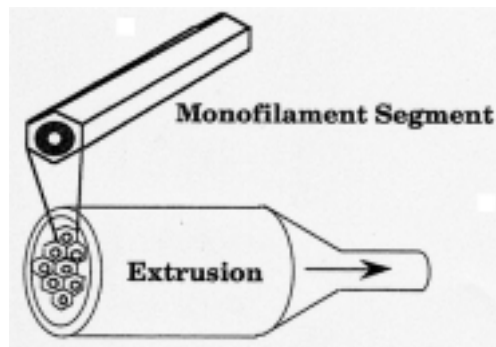
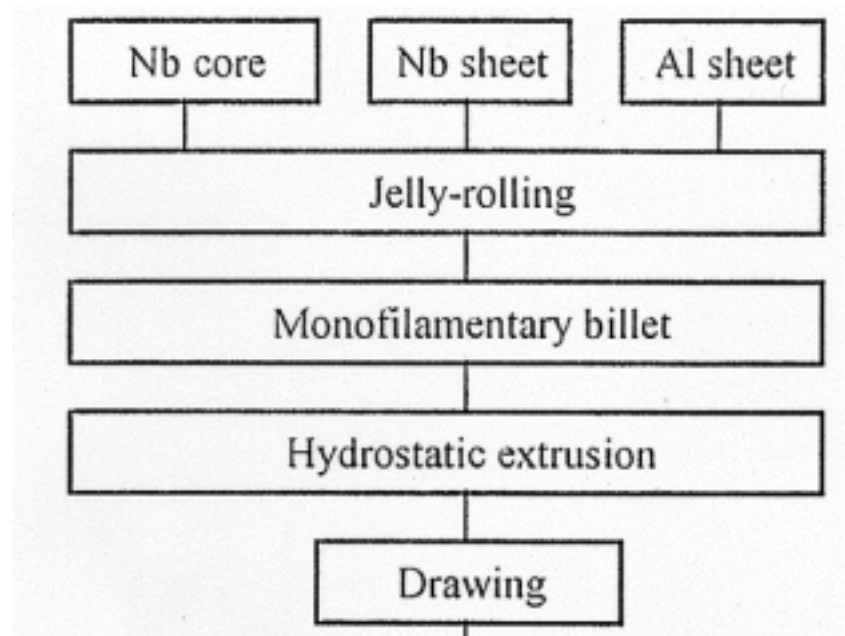


**For a given degradation of  $I_c$  at 12T, Nb<sub>3</sub>Al tolerates about twice the strain of the Nb<sub>3</sub>Sn.**

$I_c$  degradation, caused by stress or strain, becomes larger at higher field.

Appl. Phys. Lett. 71(1),7 (1997) p.122. by T. Takeuchi et al.

# Fabrication process of RQ-JR wire

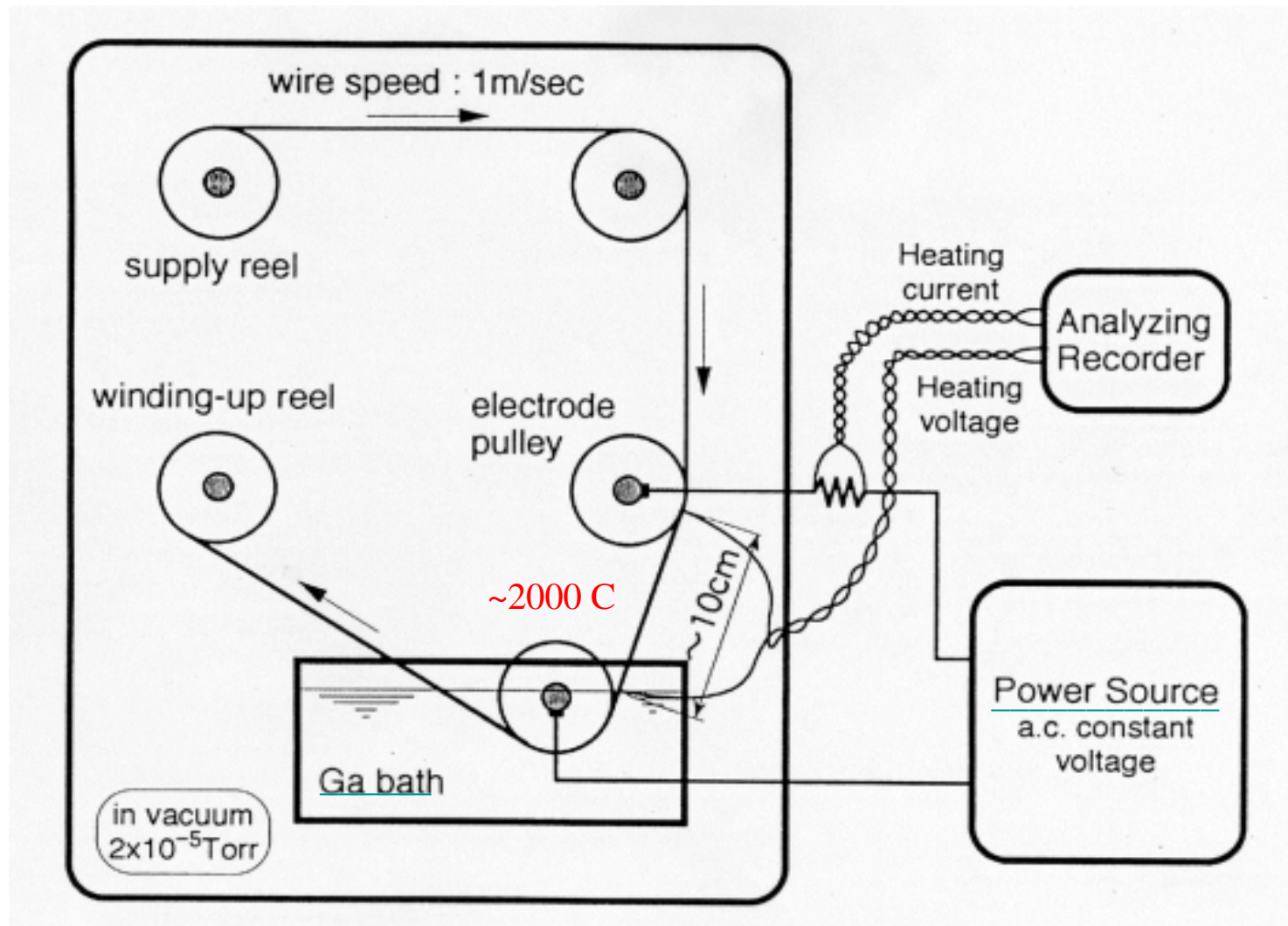


bcc Nb(Al)ss

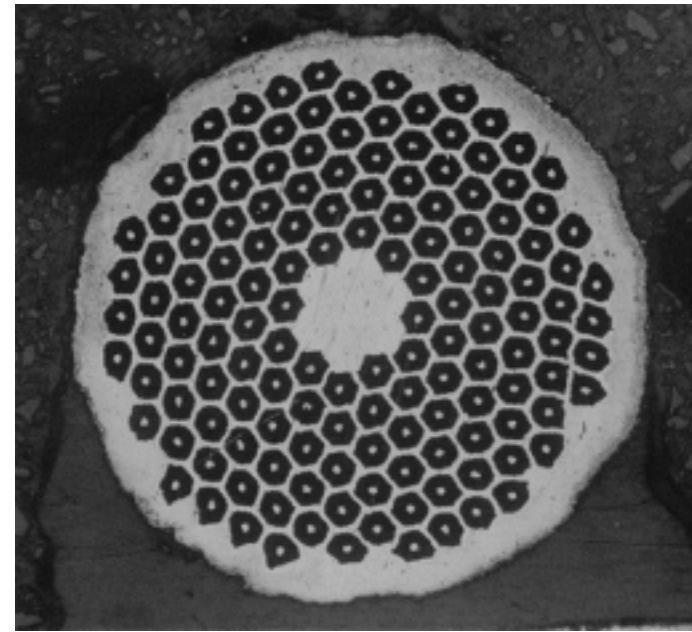
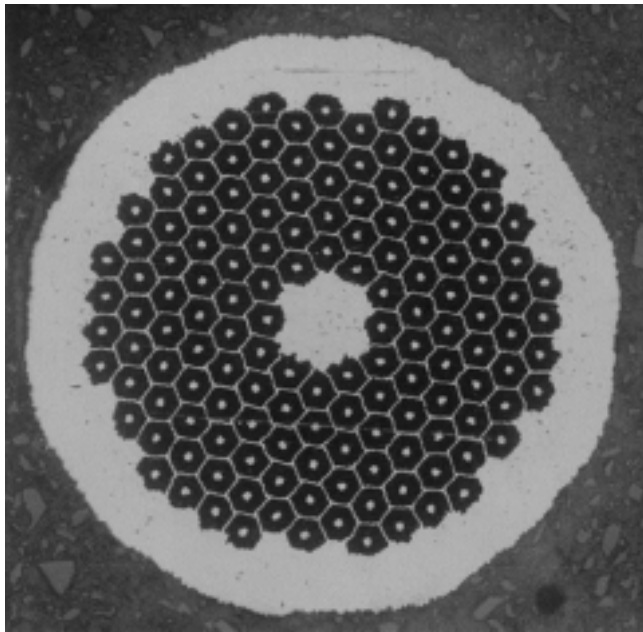
800 C x 10 h

A-15 Nb<sub>3</sub>Al

# Rapid quenching apparatus



# Typical cross sectional image of $\text{Nb}(\text{Al})_{\text{ss}}/\text{Nb}$ composite



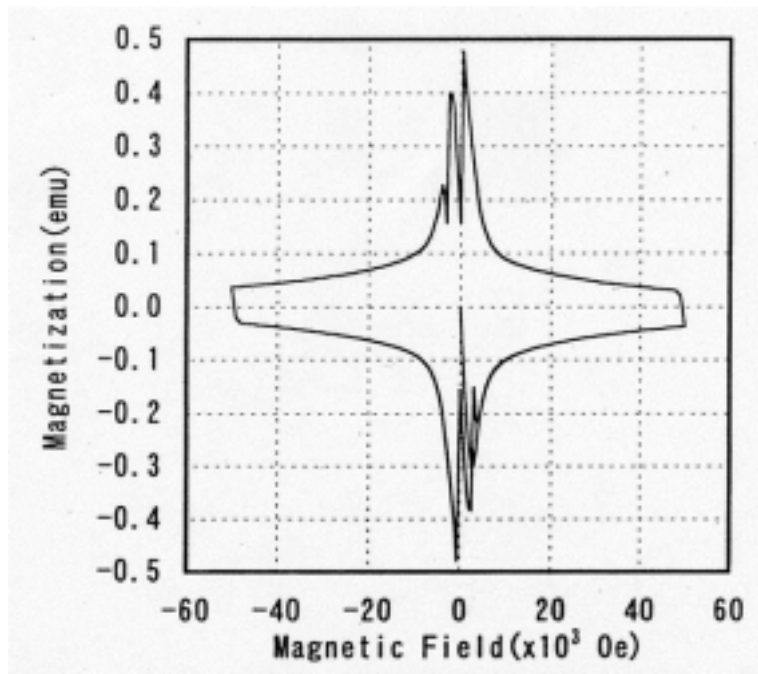
<b>Wire dia.:</b>	<b>0.8 mm</b>
<b>Filament dia.:</b>	<b><math>\sim 55 \mu\text{m}</math></b>
<b>Matrix ratio:</b>	<b>1.0</b>
<b>Num. of filaments:</b>	<b>144</b>

# Features of RQ Nb<sub>3</sub>Al wire

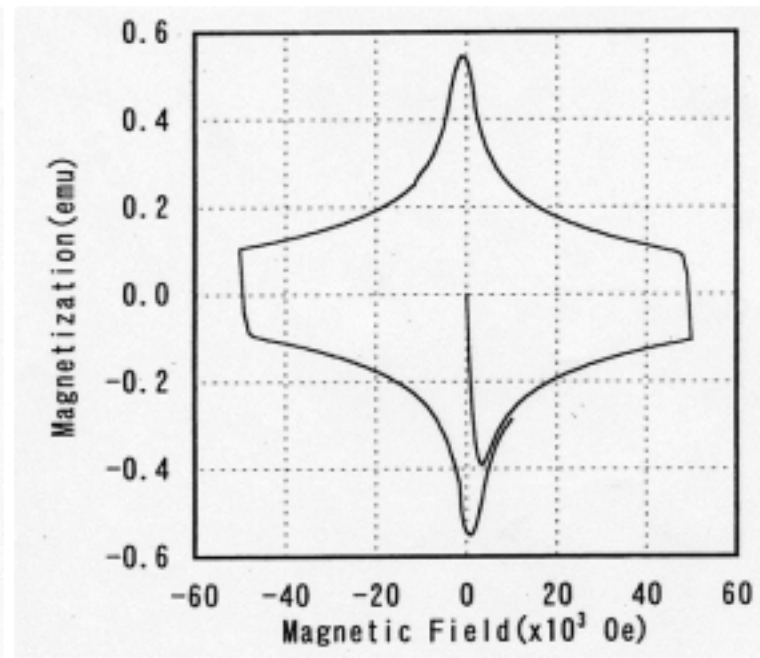
- **Nb matrix**
  - How to incorporate copper stabilizer  
electrical Cu plating, mechanical cladding
  - Magnetization of Nb
- **bcc Nb(Al)ss has good ductility at room temp.**
  - RQ wire can be bent, stranded to a cable and wound to a coil before making A-15 phase
  - **J<sub>c</sub> can be increased by area reduction of the wire**



# Magnetization curves for Nb<sub>3</sub>Al wires



**Nb matrix**



**Ta matrix**

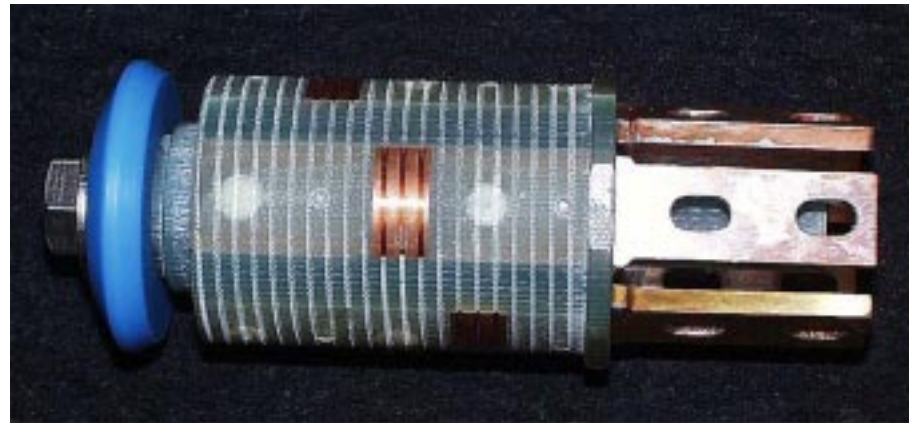
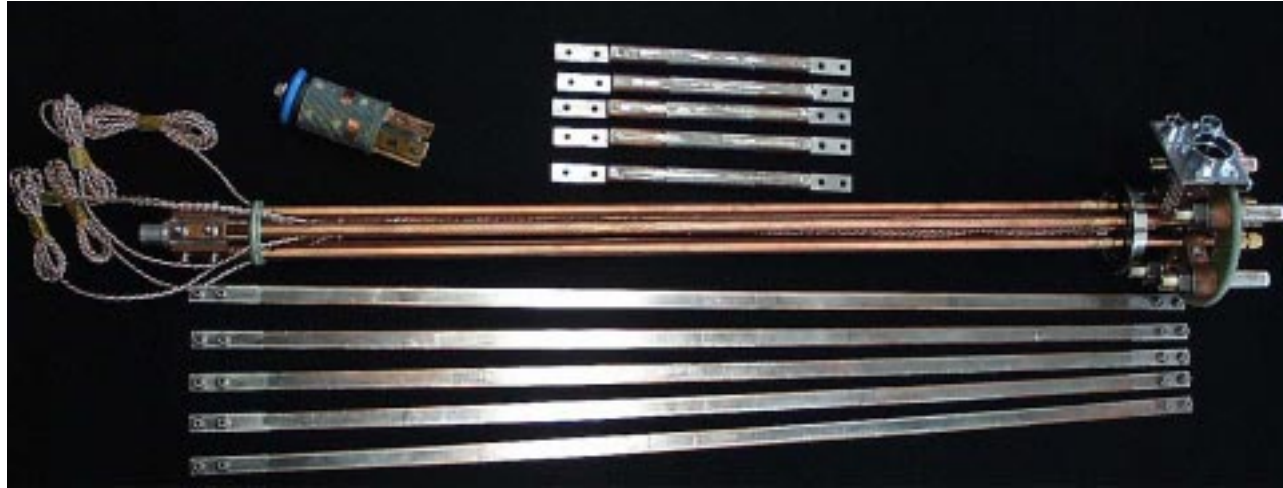
## Development target

- **Jc (non copper, 10T, 4.2 K): 2,000 A/mm<sup>2</sup> or more**
- **Wire diameter: 0.6 - 0.8 mm**
- **Effective filament size: 50 μm or less**
- **Copper stabilized wire**

# Progress

- Development of large  $I_c$  measurement holder
  - current capacity  $\sim 1000$  A, 4 samples
  - sample length: 300 mm ( $I_c$  criterion:  $3 \mu\text{V}/15$  cm)
  - $B_{\text{ext}}$ : 0  $\sim 17$  T @ 4.2 K
- Development of Copper electro-plating technique
  - $\sim 0.2$  mm thickness
- Preliminary study to increase  $J_c$ 
  - effect of barrier thickness between filaments
  - effect of heat treatment conditions
  - effect of area reduction of the RQ wire

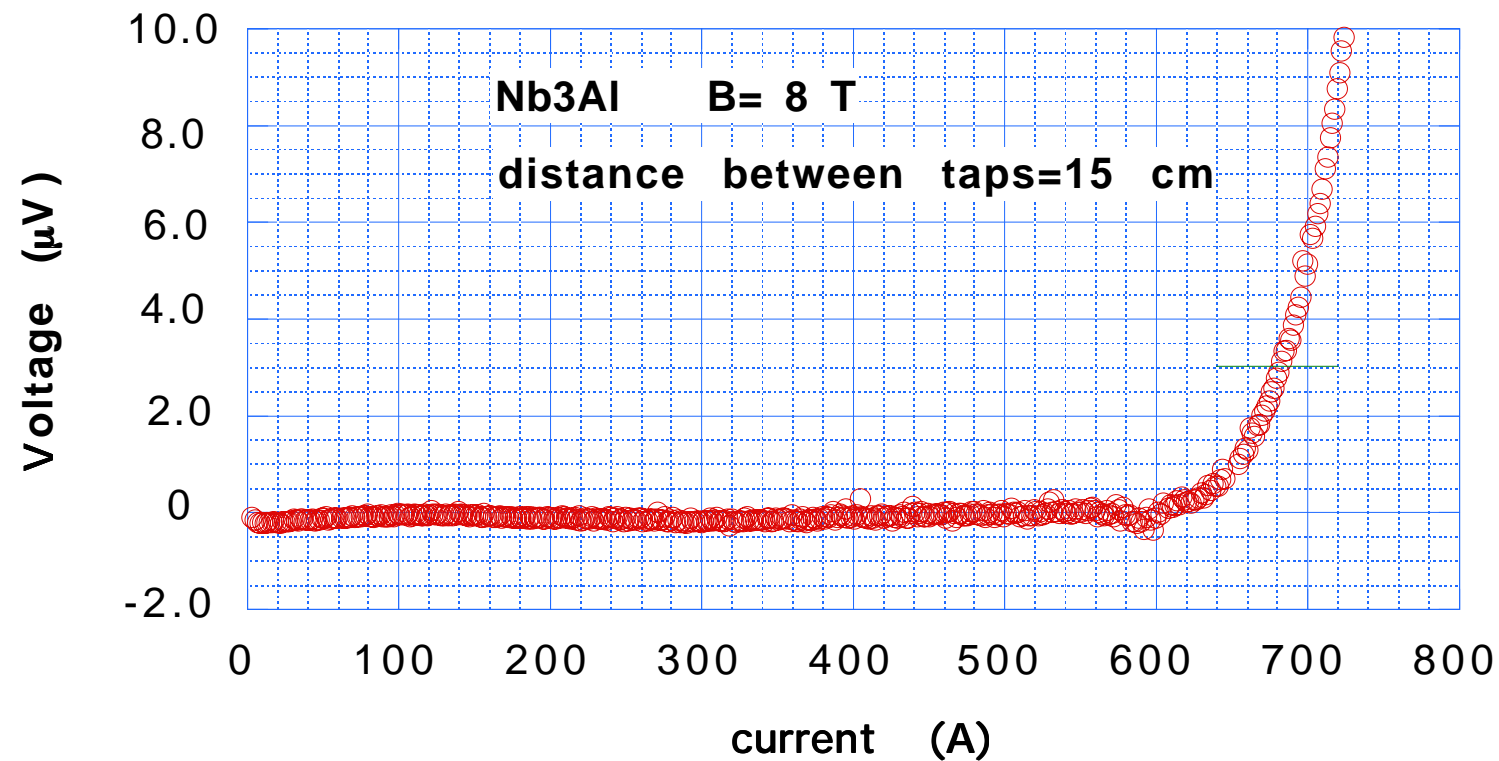
## Large $I_c$ measurement holder



**Typical ramp rate: 4.5 A/sec  
for 1000 A**

**Heating at 1000 A: less than 80 mW/lead ( $\Delta T < 10$  mK)**

## Typical V-I trace of Nb<sub>3</sub>Al wire



# Nb<sub>3</sub>Al R&D present status

## • non copper Jc

Wire dia.: 0.69 mm

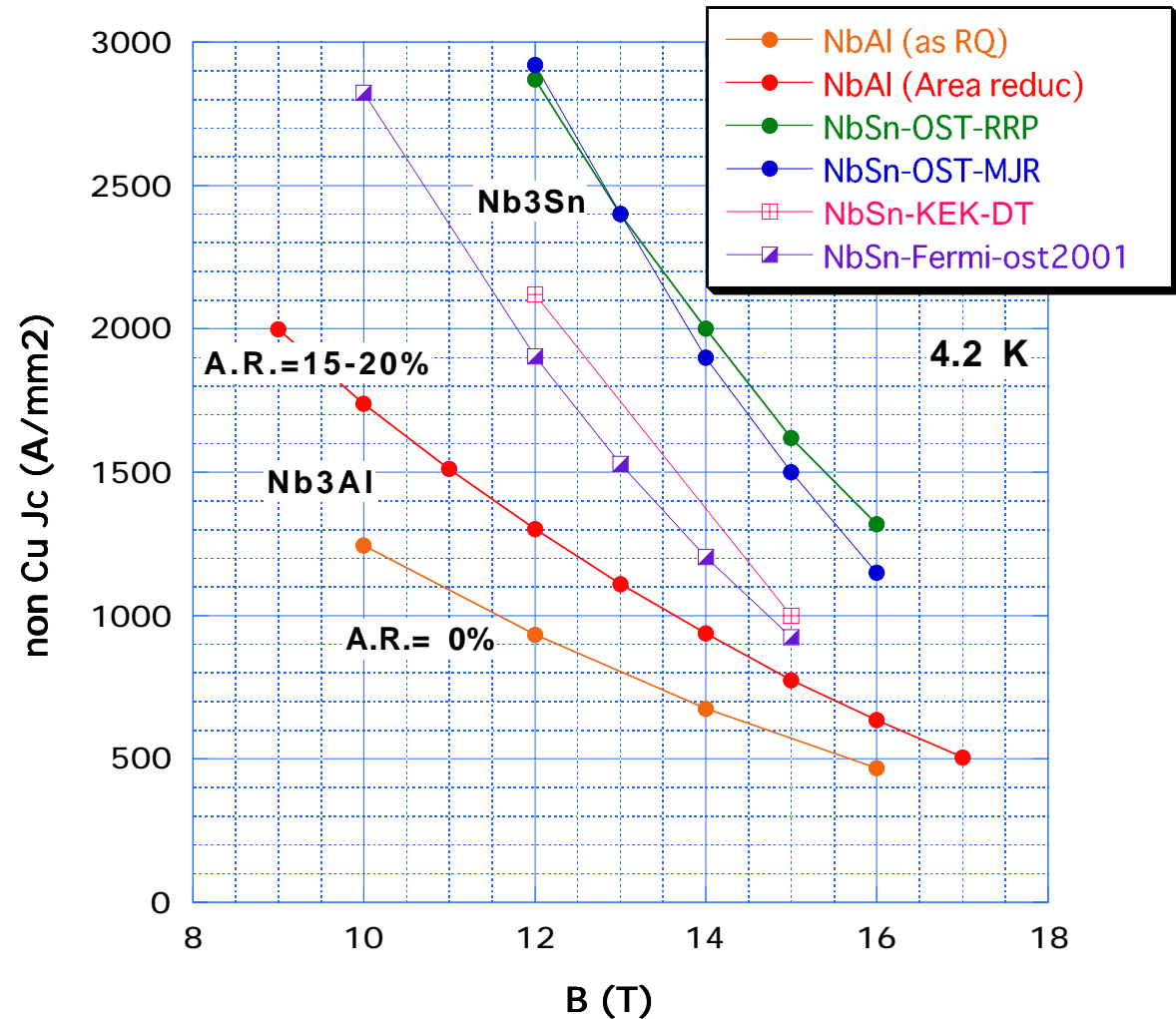
Matrix ratio: 1.0

Filament dia.: 50  $\mu$ m

Jc = 1738 A/mm<sup>2</sup> @ 10 T

1303 @ 12 T

775 @ 15 T



## - Steps toward improvements in Jc

- Reduce the matrix ratio

*1.0 to 0.8 will increase the  $J_c$  about 11 %*

*1.0 to 0.6* 25 %

- Optimize the area reduction ratio

- Optimize the heat treatment conditions

- **Stabilization technique**

- electro-plating technique is usable for  $I_c$  test

- need new technique to get better contact between Cu and Nb

## • Production scale

- piece length :  $\sim 300$  m

# Summary

- Preliminary studies of  $J_c$  improvements have been done. Low Nb matrix ratio wire will be investigated next.
- Large  $I_c$  measurement holder has been developed and used for the studies of  $Nb_3Al$ .
- Electro-plating technique is usable for  $I_c$  measurement, but we need new technique to get better contact between Nb and Cu.
- Present production scale is too small for acc magnet applications. It must be improved in the future.
- Since the strain tolerance of  $Nb_3Al$  is very attractive for high field magnet, the development of  $Nb_3Al$  should be continued as an alternative to  $Nb_3Sn$ .